Theses and Dissertations | 1. Thesis and Dissertation Collection, all items

1979-03

Development of information theory concepts and equations for human mental processing.

Martinez, Jose Alberto

Monterey, California. Naval Postgraduate School

http://hdl.handle.net/10945/18680

NAVAL POSTGRADUATE SCHOOL
Monterey, California
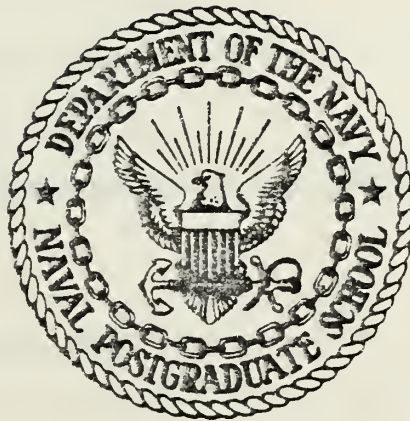
THESIS

DEVELOPMENT OF INFORMATION THEORY
CONCEPTS AND EQUATIONS FOR
HUMAN MENTAL PROCESSING

by

Jose Alberto Martinez
March 1979

Thesis Advisor: G. K. Poock

Approved for public release; distribution unlimited.

T187811

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Development of Information Theory Concepts and Equations for Human Mental Processing		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; March 1979
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jose Alberto Martinez		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE March 1979
		13. NUMBER OF PAGES 33 pages
14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/ DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Human mental processing
information theory
levels of integration
complex task

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the research and analysis accomplished in order to develop new concepts of information theory and new equations that could allow the researcher to compute with more precision, the amount of information processed by a subject during the execution of a sequential mental task.

A very sophisticated piece of equipment was used in order to simulate a sequential task of military nature. The results of the

DD _{1 JAN 73} 1473   EDITION OF 1 NOV 68 IS OBSOLETE
(Page 1)   S/N 0102-014-6601 |

experiment proved that new equations to compute the amount of information processed should be used when the task to be performed implies that the operator has to go through different levels of "thinking" before he reacts to a stimulus.

DD Form 1473
1 Jan 73
S/N 0102-014-6601

2   UNCLASSIFIED

Development of Information Theory Concepts
and Equations for Human Mental Processing

by

Jose Alberto Martinez
Captain, Peruvian Air Force
B.S., Peruvian Air Force Academy, 1972

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 1979

ABSTRACT

This report presents the research and analysis accomplished
in order to develop new concepts of information theory and new
equations that could allow the researcher to compute with more
precision, the amount of information processed by a subject
during the execution of a sequential mental task.

A very sophisticated piece of equipment was used in order
to simulate a sequential task of military nature. The results
of the experiment proved that new equations to compute the
amount of information processed should be used when the task
to be performed implies that the operator has to go through
different levels of "thinking" before he reacts to a stimulus.

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGEMENT

The author wishes to express his deep appreciation to Professor G. K. Poock and Professor D. E. Neil for their professional advice and guidance in preparing this thesis.

Special thanks are due to my wife, Patti, for her constant encouragement, numerous sacrifices, aid and understanding which provided the impetus for the completion of this project.

I. PROBLEM

A. BACKGROUND

When the concepts of information theory were developed by Wiener [1948] and Shannon and Weaver [1949], they were only applied and oriented to the field of electrical communications. Later on, the same concepts were used in other fields, such as biological, medical and psychological sciences. According to information theory, the uncertainty (H) in N messages was defined as:

$$H = \sum_{i=1}^{N} p_i \log_2 \left(\frac{1}{p_i}\right) \text{ bits} \tag{1}$$

where P = the probability of message i occurring.

This equation can be used in human information processing to assess the amount of information required to be processed by the human operator during task performance. Work to apply this equation, and other concepts of information theory, to human information processing has been done by Fitts and Posner [1967]. Scholes [1970] applied the concepts of information processing and developed cosine functions describing movements in terms of information required to be processed. Poock [1969, 1973] has shown that the principles of information theory can be applied to human physiological parameters (i.e., audition and vision).

These studies for determining the amount of information required to be processed are important because standard techniques are available for determining human information processing rates. In this way, if one knows how much information is going to be processed at a certain rate, then human performance times can be predicted. This is very important because it can be used to assess the effects caused by changing current system operating procedures which affect the compatibility of the man-machine systems or to determine when the operator is overloaded.

In general, most of the work that has been done in the area of human information mental processing is related to tasks that are very simple and of a fairly repetitive nature. But in the case of military tasks, these are not of a repetitive nature, but involve sequential operations of mental processing with "deeper" levels of thinking or integration at each stage of the task. For example, a radar operator performs detection, identification, classification and interpretation. These task activities can be thought of as becoming more complex with each successive stage; for example, classification involves previous consideration of detection and identification, and interpretation involves previous consideration of detection, identification and classification.

Hence, the more complex the levels of integrative processing become, the larger the information which the operator processes becomes. Van Gigch [1970] proposed a model that was based on the different levels of integration that are involved in the completion of a task. He defined four levels of integration

9

and derived different equations for each of them. The equations for the different levels of integration were:

$$H = \sum_{i=1}^{N} p_i \log_2 (\frac{1}{p_i})^K \text{ bits} \qquad (2)$$

where K = 1 for H(1) or first level of integration

K = 2 for H(2) or second level of integration

K = 3 for H(3) or third level of integration

K = 4 for H(4) or fourth level of integration.

Van Gigch stated that there was no mathematical justification for the values assigned to the coefficient K, but he felt the new coefficients described a new approach that had to be validated by the use of a complex task. He pointed out that his model could be applied to military operations. Thinking of the radar operator case, it can be seen very clearly that there is a similarity between Van Gigch's model and military tasks. Van Gigch, in his paper, recognized the fact that as the task becomes more complex, more information should be processed. This is the main idea of his paper and the meaning of his new formulas. In this way, more information is processed as the level of integration is higher.

B. OBJECTIVES

Based on these ideas, the objectives of this experiment were divided as:

1. Use the values of K proposed by Van Gigch in order to compute the amount of information H(i) and use these values of H(i) to predict reaction times for any human being.

10

2. Develop a procedure allowing the computation of values for K. In other words, start with the idea that the equations for H have the form presented by Van Gigch, but compute the values for K, and use these values to predict reaction times.

3. Find correlation coefficients (RHO) between predicted times and observed times for the subjects that were used in the validation phase. These correlation co-efficients will provide the acid test of how good the computed equations were.

II. METHOD

A. DESIGN

Equipment allowing representation of the four levels of
integration was sought. The apparatus that had almost all
of the necessary characteristics was the Response Analysis
Tester (RATER), built by General Dynamics Corporation. This
apparatus matched almost perfectly the characteristics that
this experimenter wanted, in order to reflect the complexity
of a task. In this way,

First level of Integration = H(1) = Delay 0

Second level of Integration = H(2) = Delay 1

Third level of Integration = H(3) = Delay 2

Fourth level of Integration = H(4) = Delay 3

were defined. These definitions allowed the experimenter to
match the model of Van Gigch with the RATER and a military
task, (i.e., radar operator task). For each of the subjects,
information as to age, number of correct responses, total
responses, and average reaction time was collected.

Average reaction time was chosen as the dependent varia-
ble. Given as to the difficulty of recording pure reaction
time in the RATER (time between the onset of the stimulus and
completion of the response), the use of average reaction time
was considered appropriate, and was defined as the duration
of the test, chosen to be three minutes divided by the number

of correct responses. Because the purpose of this experiment
was to develop equations for human information processing,
this experimenter considered it reasonable to subtract the
movement of the hand of the subject when he answered a
stimulus. In order to achieve this goal the Information
Processing Rate Device was used. Every one of the subjects'
movement time was measured by the use of this apparatus, and
this time was subtracted from the average reaction time
recorded for the RATER. In this way pure reaction time was record-
ed.   The sheet that was used to record the different informa-
tion is described in Appendix A.

B. APPARATUSES

   1. Response Analysis Tester (RATER)

        This device built by General Dynamics Corporation, is
a very sophisticated psychomotor-testing instrument designed
to provide sensitive and reliable measurement of response
speed, accuracy and short term memory which incorporated four
delay modes.
        It consisted of the experimenter's console and the
subject's console. The first one contained all the switches
to represent the different delay modes. The second one con-
sisted of a viewing window and four buttons representing
each of the symbols that could appear on the viewing window.
The basic task required the subject to press the correct
response button for each of four symbols. The possible
symbols were diamond (◇), circle (0), plus sign (+), and

13

triangle (Δ). They were automatically displayed in a continuous random sequence in such a way that the subject could not have out-guessed the next symbol which was to appear. When the symbols were equally likely to appear, the equations were simplified to the following form:

$$H(i) = \log_2 (N)^K \text{ bits} \tag{3}$$

Applying equation (3) with the number of alternatives (N) equal to four, we have:

$$H(i) = \log_2 4^K = K \log_2 4 = 2K \text{ bits} \tag{4}$$

The settings used during the operation of the RATER were:

Duration of test:	1 minute (practice trials) 3 minute (real experiment)
Pace mode:	self-pace
Response pattern:	1
Delay mode:	according to the mode being used.
Rate of Presentation:	non-applicable under self-pace.

The use of the self-pace mode allowed the subject to respond to as many stimuli as he could, during the three-minute session.

2. Information Processing Device

The use of this device allowed the experimenter to get the movement time of the subject. Twenty symbols (number 1) were presented and the total reaction time was recorded.

14

This apparatus, as with the RATER, consisted of two consoles;
the experimenter's and the subject's. The experimenter's
consisted of a synchronous electric clock (to record reaction
time), and a small console that had a button which needed to
be pressed in order to present the stimulus to the subject.
The subject's console consisted of a viewing window where the
symbol (number 1) appeared, and a response console containing
four buttons where only the one button corresponding to the
number one was used. In this way, no decision was made by
the subject, and only movement time could be recorded.

C. SUBJECTS

Subjects were 20 randomly selected students from the
Naval Postgraduate School. Their ages ranged from twenty-four
to thirty-eight year old, with no known mental or physical
disorders. The mean age for the subjects was 29.9. Nineteen
of the subjects were male and one female; all eager to partici-
pate even though none of them received any compensation for
his or her participation in the experiment.

D. PROCEDURE

The experiment was conducted in the Man-Machine Systems
Design Laboratory at the Naval Postgraduate School in an
environmental chamber. The experiment, as explained before,
was divided into two parts. The first part was done by the
use of the RATER. After the subject entered the chamber and
sat before the RATER's response console, which was also

located in the chamber, the following instructions were read:

> "The experiment in which you have been chosen to
> participate is a test of your response speed and
> accuracy. Four different symbols (plus sign,
> circle, triangle, and diamond) will appear
> randomly in the viewing window. Each of the
> four response buttons below the viewing window
> corresponds to one of the four symbols. Your
> task will be to respond to each symbol according
> to the instructions that will be read before each
> part of the experiment. When you press the
> correct button, another symbol will appear. If
> your response was incorrect, the symbol will stay
> there until you make the correct response. Remem-
> ber, this test measures "speed" and "accuracy;"
> if you press more than one button at a time, an
> error will be recorded. Symbols' appearances
> are completely random, so do not try to anticipate
> which symbol will show up next. The experiment
> will consist of four parts, which we will call
> Delay 0, Delay 1, Delay 2, and Delay 3, respective-
> ly. Previous to each part, ten practice trials
> will be given to you.

> Place the thumb and forefinger of each hand on the
> response buttons; maintain this position through-
> out the whole experiment."

After these instructions were heard, the subject performed

the Delay 0 mode. Before this, he listened to the instruc-

tions that explained how that mode worked. These instructions

were:

> "Watch for the ready light. Begin responding when
> the first symbol appears and continue to respond
> until the test light goes off. You will be given
> one minute practice trial in this position before
> you are timed. Do you have any questions?"

After this part, instructions for the Delay 1, 2, and 3

were read to the subject. These instructions were:

"In the delay mode, your task is to note the
symbols as they are presented but to delay
your response until one or more symbols have
intervened. You will be told how long to
delay your response. For example, with one-
symbol delay in the self-pace mode, a symbol
will appear which you should note and remember.
When the next symbol appears, your response
should be the normal correct response to the
previous symbol which is no longer present.
At the same time, note the symbol present
because it will determine the correct response
for the next interval. In other words, you
are responding in a continuous sequence, except
that you are delaying, or shifting, your
sequence of responses by one symbol. The same
principle applies for delays of two, three and
four symbols. To start responding in the delay
mode, you must view one or more symbols prior
to your first response. RATER presents the
required number of symbols and then holds the
following symbol until you make your first
correct delay response."

After these instructions, the ones corresponding to Delay

1 were read. These were:

"We will now do Delay 1. You will respond to the
symbol that was on just before the one that is
currently displayed. In this case, the first
symbol will appear and will be followed by the
second symbol which will be on for an indefinite
length of time until you respond correctly to
the first one. Then the third symbol will appear,
and to that you must respond correctly to the
second one that was presented and so on, so that
you are always responding one back from the one
that is currently displayed. You will be given
one minute practice trial in this mode before
you are timed. Do you have any questions?"

After this part, the instructions for Delay 2 were read

as follows:

"In the next set of trials, your task will be
to respond to the symbol that was on two back
from the one that is currently displayed. This
is called Delay 2. What you will see this time
is the first symbol; it will be followed by the

second symbol and then the third symbol will appear. When the third symbol is displayed, you will respond to the first one that was displayed, and when the fourth one comes on, you will respond to the second symbol that was displayed so that you are always responding two back from the one that is currently on. You will be given one minute practice trial before you are timed. Do you have any questions?"

Once this part was finished, part four (Delay 3) was started with the reading of the following instructions:

"On this set of trials, you are to respond to the third one back from the one that is displayed now. This is called Delay 3. In this case, the first symbol will be displayed followed by the second symbol, and then the third, and then the fourth will be displayed for an indefinite period of time until you respond correctly to the first one. When the fifth symbol appears, you are to respond to the second symbol that was on, and so on so that you are always responding three back from the one that is currently displayed. You will be given one minute practice trial before you are timed. Do you have any questions on this procedure?"

The second part of the experiment consisted of the use of the information processing device. In this part, the "number one" (stimulus) was presented 20 times and total reaction time recorded by an electric clock. Before this part started, the following instructions were read to the subjects:

"Sit up straight in your chair and place your hand atop the metal box with your thumb on the button that is marked with the "number one." Every time that you see the number one displayed in the viewing window, press the button as quickly as possible. Remember; use your thumb.

After this part is finished, the same work will be done with your forefinger. Do you have any questions?"

18

This was the last part of the experiment. The subjects were divided into two groups chosen before the execution of the experiment. Fifteen of them were used to compute the new equations (values of K) and five subjects were used in the validation phase. The first group was comprised of the first 15 subjects, and the second group consisted of the remaining five subjects. There was no special reason for the use of this method of selection.

Each of the twenty subjects was assigned the same testing sequence (Delay 0, Delay 1, Delay 2, Delay 3). The reason for the use of the same sequence was that the author considered that the degree of difficulty of the task increased when the time that the subject had to delay his response increased. Therefore, the use of the same sequence for each subject, ordered by the time of delay of the response allowed him to get more acquainted with the apparatus, yielding as a result a better performance in the delay modes with higher degree of difficulty.

III. RESULTS

A. DATA

The data of each subject was recorded in the coding sheet described in Appendix A. A summary of the data is presented in Appendix B.

B. ANALYSIS OF THE DATA

Two procedures were employed in order to satisfy the objectives of the experimenter.

1. Using Van Gigch's Model

The number of alternatives (N) was four. Using equation (2), the amount of information processed in each delay mode was computed. Also, the means of the pure reaction time (RT) for the 15 subjects in each delay mode were computed. The data is shown in Table I.

	K	H(i) bits	RT(i) Seconds
DELAY 0	1	2.0	0.67205
DELAY 1	2	4.0	1.2865
DELAY 2	3	6.0	2.1075
DELAY 3	4	8.0	2.3248

TABLE I. Raw values of K, H(i), and RT(i) of 15 subjects.

	K	$\sqrt{H(i)}$	$\sqrt{RT(i)}$
DELAY 0	1	1.4142	0.81979
DELAY 1	2	2	1.1343
DELAY 2	3	2.4495	1.4517
DELAY 3	4	2.8284	1.5247

TABLE II. Transformed values of K, H(i), and RT(i) of the 15 subjects.

Using H(i) as the independent variable and RT(i) as the dependent variable, a regression analysis was performed, but previous to the execution of this analysis the data was submitted to a transformation in order to satisfy statistical conditions, McNeil [1977]. The transformation that was applied was the square root. The raw data and transformed data are shown in Tables I and II, respectively.

Using the transformed data, the following regression line was computed in order to be able to predict reaction times for the five subjects used in the validation phase. This equation was:

$$\sqrt{\widehat{RT}} = 1.2326 + 0.5238(\sqrt{H} - 2.173) \qquad (5)$$

Using the regression equation and concepts developed by Brownlee [1965], confidence intervals for each of the delay modes were computed. These results are shown in Table III. It is necessary to quote that the boundaries of the intervals are given in the scale of the raw data. With these confidence intervals already computed, the observed average reaction times of the five subjects used in the validation phase

(Appendix B), were checked to find if they fell between the
boundaries of the different confidence intervals. In this
way, under Delay 0, the average reaction times of the five
subjects fell between the limits of the 90% and 95% confidence
intervals; for Delay 1, four and three observed times fell
between the boundaries of the confidence intervals; for
Delay 2, four and three; and for Delay 3, five and three.

These results proved that the values of K, proposed
by Van Gigch, were acceptable. The experimenter felt that a
correlation coefficient between predicted and observed times
would be a good approach. The predicted times for the four
delay modes were computed using equation (5), to derive:

$$\widehat{RT} = \left[1.2326 + 0.5238(\ H \ - 2.173)\right]^2 \qquad (6)$$

This better expresses the reaction time in the terms of the
original scale.

The correlation coefficients between observed and
predicted times for every one of the five subjects were:
0.96251, 0.96618, 0.90273, 0.97858, and 0.97879. As it can
be observed, all the correlation coefficients were very high.
The data used to compute the five correlation coefficients is
shown in Appendix C.

2. Using the Information Processing Rate

Hick [1952] defined Information Processing Rate (IPR)
by the following equation:

$$IPR = \frac{H}{RT} = \frac{BITS}{SECONDS} \qquad (7)$$

	DELAY 0	DELAY 1	DELAY 2	DELAY 3
95%	$0.2149 \leqslant \hat{RT} \leqslant 1.4562$	$0.6826 \leqslant \hat{RT} \leqslant 2.1250$	$1.1163 \leqslant \hat{RT} \leqslant 2.8843$	$1.4846 \leqslant \hat{RT} \leqslant 3.738$
90%	$0.3399 \leqslant \hat{RT} \leqslant 1.1822$	$0.8607 \leqslant \hat{RT} \leqslant 1.8394$	$1.3448 \leqslant \hat{RT} \leqslant 2.5447$	$1.7778 \leqslant \hat{RT} \leqslant 3.3069$

TABLE III. Confidence intervals for the Van Gigch model.

Using this equation, the experimenter computed new values for K. The procedure is based on the concept that in Delay 0, the formula with a K value of one is reasonable because the task did not involve a significant degree of difficulty. Using the information processing rate as a base line, the following identity was developed:

$$\frac{H(1)}{RT(1)} = \frac{H(2)}{RT(2)} = \frac{H(3)}{RT(3)} = \frac{H(4)}{RT(4)} \tag{8}$$

But this identity can be rewritten in the following form:

$$\frac{H(1)}{RT(1)} = \frac{\log_2 4^k}{RT(i)} \text{ for } i = 2, 3, 4 \tag{9}$$

This equation was based on the idea that under Delay 1, 2, and 3, more information should be processed, given that the time spent in answering the stimulus was larger than the one recorded under Delay 0.

From equation (9), a formula for K was derived:

$$K = \left[\frac{H(1)}{RT(1)}\right] \left[\frac{RT(i)}{\log_2 4}\right] \text{ for } i = 2, 3, 4. \tag{10}$$

Using this equation (10), values for K were computed and used to compute the amount of information processed under each of the delay modes. These results are shown in Table IV. Using the results of Table IV, the following regression line was computed:

$$\widehat{RT} = 1.5977 + 0.33603 \ (H - 4.7548) \tag{11}$$

Using this regression equation (11), correlation coefficients between observed and predicted values were computed. These

were: 0.92748, 0.93854, 0.94605, 0.93544 and 0.99493. The

data used to compute the correlation coefficients is shown

in Appendix D. As in the case of Van Gigch's model, the

predicted values were high and the values for K were very

close to the ones that Van Gigch proposed.

	K	H(i) bits	RT(i) Seconds
DELAY 0	1.0	2.0	0.67205
DELAY 1	1.9143	3.8286	1.2865
DELAY 2	3.1359	6.2718	2.1075
DELAY 3	3.4593	6.9186	2.3248

TABLE IV. Values of K, H(i), and RT(i) computed
by the use of the Information Processing
Rate Model.

IV. DISCUSSION AND CONCLUSIONS

The results showed that reaction time increased when the amount of information increased. This ratified the results of previous experiments performed by other authors. Both methods, the Van Gigch method and the one that the experimenter developed, yielded similar results, but a higher correlation was obtained by the use of Van Gigch's model. Based on these results, the experimenter accomplished his objectives, concluding that new equations should be used when the task to be performed has the characteristics of the ones described by Van Gigch or are of a military nature. In this way, the new equations should be:

$$H(1) = \log_2 N$$

$$H(2) = \log_2 N^2$$

$$H(3) = \log_2 N^3$$

$$H(4) = \log_2 N^4$$

In all cases the results were computed for the number of alternatives (N) equal to four, and stimuli equally likely to occur. The procedure developed by the experimenter justified and verified the theoretical model described by Van Gigch, but in an experimental manner.

Further research is recommended in the following areas:

1. Perform the same analysis but use a piece of equipment that allows the use of more than four stimuli and different probability of occurrence.

26

2. Try to connect the RATER to the computer (PDP-8) in order to record reaction time, avoiding the use of average reaction time.

3. Simulate the RATER in a computer; this procedure could be used in case the connection of the RATER to the PDP-8 is not possible. This could be done in a computer that has special registers that can be used for this problem (I. E. Burroughs B-3500).

Finally, the experimenter would like to explain why Van Gigch could have chosen the values 1, 2, 3 and 4 for K. In other words, how his concepts were applied to the RATER.

In Delay 0, one stimulus was presented out of four possible and an immediate response was required. In this case, there was no problem, two bits were processed. In Delay 1, one stimulus was presented; the second one was presented and a response given to the first one; the third was presented and a response given to the second one, etc. In this case, the subject answered one back, having processed two bits from the first stimulus and two bits from the second one, this made $2 + 2 = 4$ bits. In Delay 2, the subject had to process $2 + 2 + 2 = 6$ bits to make one response. In Delay 3, the subject had to process $2 + 2 + 2 + 2 = 8$ bits to make one response.

APPENDIX A

SHEET USED TO RECORD THE DATA

SUBJECT NO.:

AGE   :

INFORMATION PROCESSING DEVICE

	TRT	ART1
THUMB		
FOREFINGER		

$$\overline{ART1} =$$

RATER

	TR	CR	ART2	PRT
DELAY 0				
DELAY 1				
DELAY 2				
DELAY 3				

TRT : Total reaction time for the Information Processing Device

ART1: Average reaction time $= \dfrac{TRT}{20}$

$\overline{ART1}$: $\dfrac{ART1 \ (THUMB) \ + \ ART1 \ (FOREFINGER)}{2}$

TR : Total responses for the RATER

CR : Correct responses for the RATER

ART2: Average reaction time for the RATER $= \dfrac{180}{CR}$

PRT : Pure reaction time $= ART2 \ - \ \overline{ART1}$

28

APPENDIX B

SUMMARY OF THE DATA COLLECTED

SUBJECT	AGE	PRT			
		DELAY 0	DELAY 1	DELAY 2	DELAY 3
1	30	0.79601	1.1780	1.7470	2.1438
2	30	0.64654	1.0908	2.1375	2.2727
3	24	0.74362	1.8327	2.2865	2.5722
4	26	0.62773	2.0766	1.7618	2.0766
5.	33	0.65851	1.1047	1.4782	1.7761
6	24	0.52837	0.90541	1.1728	1.9163
7	34	0.71126	1.5492	2.7716	3.2137
8	29	0.69841	0.93767	1.6333	1.4515
9	26	0.63187	1.0178	2.1793	2.9278
10	33	0.60217	0.97833	2.1206	2.424
11	38	0.61261	1.5598	3.2848	3.7757
12	27	0.77216	1.0282	2.2628	1.9918
13	28	0.58842	1.3881	2.2665	2.4531
14	35	0.68986	0.90631	1.9326	2.2727
15	28	0.77327	1.7444	2.5776	1.6048
16	27	0.586	0.66345	1.2159	1.7129
17	29	0.53532	0.68531	1.6741	2.4433
18	32	0.59311	0.71241	3.6149	3.6149
19	31	0.82639	1.1975	2.0598	3.1183
20	34	0.6865	1.271	2.5045	2.8499

29

APPENDIX C

DATA USED TO COMPUTE CORRELATION COEFFICIENTS

FOR THE VAN GIGCH MODEL

SUBJECT 16	PREDICTED	OBSERVED
DELAY 0	0.6975	0.586
DELAY 1	1.3042	0.66345
DELAY 2	1.8973	1.2159
DELAY 3	2.4835	1.7129

SUBJECT 17	PREDICTED	OBSERVED
· DELAY 0	0.6975	0.53532
DELAY 1	1.3042	0.68531
DELAY 2	1.8973	1.6741
DELAY 3	2.4835	2.4433

SUBJECT 18	PREDICTED	OBSERVED
DELAY 0	0.6975	0.59311
DELAY 1	1.3042	0.71241
DELAY 2	1.8973	3.6149
DELAY 3	2.4835	3.6149

SUBJECT 19	PREDICTED	OBSERVED
DELAY 0	0.6975	0.82639
DELAY 1	1.3042	1.1975
DELAY 2	1.8973	2.0598
DELAY 3	2.4835	3.1183

SUBJECT 20	PREDICTED	OBSERVED
DELAY 0	0.6975	0.6865
DELAY 1	1.3042	1.271
DELAY 2	1.8973	2.5045
DELAY 3	2.4835	2.8499

APPENDIX D

DATA USED TO COMPUTE CORRELATION COEFFICIENTS

FOR THE INFORMATION PROCESSING RATE MODEL

SUBJECT 16	PREDICTED	OBSERVED
DELAY 0	0.67205	0.586
DELAY 1	1.2865	0.66345
DELAY 2	2.1075	1.2159
DELAY 3	2.3248	1.7129

SUBJECT 17	PREDICTED	OBSERVED
DELAY 0	0.67205	0.53532
DELAY 1	1.2865	0.68531
DELAY 2	2.1075	1.6741
DELAY 3	2.3248	2.4433

SUBJECT 18	PREDICTED	OBSERVED
DELAY 0	0.67205	0.59311
DELAY 1	1.2865	0.71241
DELAY 2	2.1075	3.6149
DELAY 3	2.3248	3.6149

SUBJECT 19	PREDICTED	OBSERVED
DELAY 0	0.67205	0.82639
DELAY 1	1.2865	1.1975
DELAY 2	2.1075	2.0598
DELAY 3	2.3248	3.1183

SUBJECT 20	PREDICTED	OBSERVED
DELAY 0	0.67205	0.6865
DELAY 1	1.2865	1.271
DELAY 2	2.1075	2.5045
DELAY 3	2.3248	2.8499

31

LIST OF REFERENCES

1. Brownlee, K.A., _Statistical Theory and Methodology in Science and Engineering_, John Wiley, 1965.

2. Fitts, P.M. and Posner, M.I., _Human Performance_, Brooks/Cole Publishing Co., 1967.

3. General Dynamics Corporation, _Operating Instructions for the Miniaturized Response Analysis Tester (RATER)_, 1969.

4. Hick, W.E., "On the Rate of Gain of Information," _Journal of Experimental Psychology_, V. 4, p. 11-26, 1952.

5. Kodalen, K.C., _The Effect of Complex Information Processing Techniques Applied to Short Term Memory of Military Officers_, M.S. Thesis, Naval Postgraduate School, California, Monterey, 1970.

6. McNeil, D.R., _Interactive Data Analysis_, John Wiley, 1977.

7. Poock, G.K., "Information Processing versus Pupil Diameter," _Perceptual and Motor Skills_, V. 37, p. 1000-1002, 1973.

8. Poock, G.K., and Noel, C.E., "Effects of Workplace Layout on Pupillary Diameter," _Perceptual and Motor Skills_, V. 40, p. 304, 1975.

9. Poock, G.K., Letter NC4 (55PK)/mmb to Research Council Naval Postgraduate School, Subject: _Proposal to Include Research Project in the Foundation Research Program_, 9 June 1976.

10. Scholes, E.E., _Information Capacity of Discrete Motor Responses Compared for Different Directions and Amplitudes of Movement_, M.S. Thesis, Naval Postgraduate School, California, Monterey, 1970.

11. Shannon, C.E. and Weaver, W., _The Mathematical Theory of Communications_, the University of Illinois Press, 1949.

12. Van Gigch, J.P., "A Model for Measuring the Information Processing Rates and Mental Load of Complex Activities," _Canadian Operational Research Society Journal_, V. 8, p. 116-128, 1970.

13. Wiener, N., _Cybernetics_, John Wiley, 1948.

INITIAL DISTRIBUTION LIST

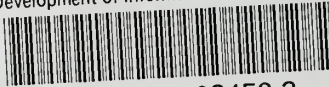No. Copies

1. Defense Documentation Center   2
    Cameron Station
    Alexandria, Virginia   22314

2. Library, Code 0142   2
    Naval Postgraduate School
    Monterey, California   93940

3. Department Chairman, Code 55   1
    Department of Operations Research
    Naval Postgraduate School
    Monterey, California   93940

4. Professor G. K. Poock, Code 55Pk   2
    Department of Operations Research
    Naval Postgraduate School
    Monterey, California   93940

5. Asst. Professor D. E. Neil, Code 55Ni   1
    Department of Operations Research
    Naval Postgraduate School
    Monterey, California   93940

6. Capt. Jose A. Martinez   2
    Ministerio de Aeronautica
    Direccion de Informatica
    Lima, PERU, SOUTH AMERICA